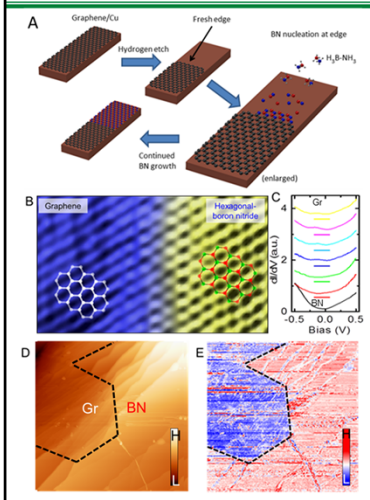
CNMS Staff Science Highlight

Heteroepitaxial Growth of Two-Dimensional Hexagonal Boron Nitride Templated by Graphene Edges



(A) Schematic of epitaxial growth of BN onto graphene edges on Cu foil. (B)-(E) Heterostructure with atomic lattice coherence and seamless boundary examined by STM (B, D) and STS (C, E).

Scientific Achievement

By adapting the concept of epitaxy to 2-dimensions, we show the growth of a single-atomic layer, in-plane heterostructure of graphene and hexagonal boron nitride (BN) coherently matched at the boundaries. The lattice orientation of monolayer BN is solely determined by the graphene, forgoing configurations favored by the supporting copper substrate.

Significance and Impact

This work unambiguously proves that a 2D crystal can grow from the edge of a 2D seed epitaxially, i.e., adapting to the crystallography of the seed, while overcoming energetic factors in its 3D environment. The created heterostructure provides a platform for exploring peculiar interfacial properties associated with the polar-on-nonpolar coherent boundary in 2D.

Research Details

- Heterostructures are grown with chemical vapor deposition on a copper foil.
- The structural and electronic properties of the heterostructures are studied by scanning tunneling microscopy/spectroscopy (STM/STS), low-energy electron microscopy (LEEM), and scanning transmission electron microscopy (STEM).

L. Liu, J. Park, D. A. Siegel, K. F. McCarty, K. C. Clark, W. Deng, L. Basile, J. C. Idrobo, A.-P. Li, and G. Gu *Science.* DOI: 10.1126/science.1246137

Work was performed at CNMS-ORNL, the University of Tennessee, and Sandia National Laboratories.

U.S. DEPARTMENT OF ENERGY | Office of Science | Sandia National Laboratories | THE UNIVERSITY of TENNESSEE KNOXVILLE | Center for Nanophase Materials Sciences AT OAK RIDGE NATIONAL LABORATORY | OAK RIDGE National Laboratory

Highlight Narrative

In this paper, *we created an ordered atomic sheet consisting of two dissimilar materials with an atomically abrupt heterojunction and lattice coherence that does not depend on the lattice of the underlying support*.

We project the concept of heteroepitaxy to two-dimensional (2D) space to demonstrate a single-atomic layer, in-plane heterostructure based on two prototypical materials that share the same crystallography -- graphene and hexagonal boron nitride (BN). Monolayer BN grows from fresh edges of monolayer graphene with lattice coherence, forming an abrupt boundary, or one-dimensional (1D) interface. More important, the crystallography of the BN is *solely* determined by that of the graphene seed, forgoing the orientations it would assume if grown independently on the supporting Cu substrate.

The novelty of this work lies in the concept of epitaxy in 2D. We view the 1D edge of the graphene seed crystal as the “substrate” in 2D space, while the catalytic copper supporting substrate merely confines the growth process to its surface – the 2D space where the epitaxy happens. The new vantage point inspires us to leverage the common wisdom in the art of conventional epitaxy in 3D, simply by reduced-dimension analogy.

This demonstration is of fundamental significance and broad importance to the scientific community. This work is an important step towards the *experimental* exploration of 2D heterostructures, especially the polar-on-nonpolar growth, which leads to the antiphase phenomenon and the polarity discontinuity. There is a vast body of theoretical literature predicting wonderful physical properties of this peculiar boundary, in absence of any experimental validation so far. This demonstration by itself will enable the probing of the predicted boundary state, and future work on utilizing 2D epitaxy to grow new 2D heterojunctions with impacts to spintronics, magnetism, and low-dimensional solid-state physics in general.

Reference:

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Science. **DOI:** 10.1126/science.1246137

Acknowledgement of Support: A Portion of this research was conducted at the Center for Nanophase Materials Sciences (CNMS), which is sponsored at Oak Ridge National Laboratory by the Scientific User Facilities Division, Office of Basic Energy Sciences, U.S. Department of Energy. This work was partially supported by NSF (ECCS-1231808), DARPA (approved for public release; distribution is unlimited), and the National Secretariat of Higher Education, Science, Technology and Innovation of Ecuador (SENESCYT). Work at Sandia was supported by the Office of Basic Energy Sciences, Division of Materials and Engineering Sciences, U. S. Department of Energy under Contract No. DE-AC04-94AL85000.